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A INVESTIGATION ON MECHANICAL AND METALLURGICAL PROPERTIES OF STEEL EN24 AND SIC MMCS

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ABSTRACT

In this present research work, microstructure and mechanical properties of steel EN 24 and SiC metal matrix composites were investigated. The composites were prepared using liquid metallurgy process in which steel EN24 as a matrix and SiC as reinforcement. The content of silicon carbide in the steel EN24 matrix varied from 2 to 6% (by weight) in steps of 2%. The annealing heat treatment was carried out on the prepared composites to make them machinable and to relieve the initial thermal stress and also to nullify the effect of directional solidification. On the freshly prepared composite specimens, Brinell's Hardness tests were carried out, it showed an increase in hardness with increasing percentage of SiC, maximum increase was obtained 298BHN for the specimen with 6% SiC. When the compressive strength was computed, the compressive strength has increased to 44kg/mm2 when the base metal was reinforced with 6% of SiC.

KEYWORDS: Steel EN24, SiC as Reinforcement & Micro Structural Analysis

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Original Article

INTRODUCTION

Metal Matrix Composites (MMCs) are fabricated by the appropriate mixture of Matrix and Reinforcement [1]. Steel based Metal Matrix Composites (MMCs) exhibit better hardness, good impact toughness, dynamic strength and exclusive fracture toughness [2,7]. The optimal composition and better dispersion of SiC particles in the steel matrix contributes extreme hardness and better wear resistance [3,8] along with very high strength as well as toughness of the base material. MMCs are gaining widespread popularity in several areas of applications related to automobiles, space, defence, aerospace, and sports segments [10]. Metal Matrix Composites are fabricated by various methods like powder metallurgy technique, squeeze casting and stir casting techniques. The mechanical property of these composites mainly depends on the type matrix material, chemical composition, size and weight of the reinforcement material and method used to fabricate these composites. The dispersion of the hard ceramic reinforcement particles in the metal matrix is affected by many factors like the method used for mixing, type of binder used, method of compaction, the way it is cast, pouring temperature [12], bonding of reinforcement particles in the matrix during mixing, compaction, and sintering. Homogeneous mixing of powder is one of the greatest problems in the preparation of metal matrix composites by powder metallurgy technique. The stir casting technique is used to fabricate the composites [13]. The process is very simple, and can be used for mass production and it is also widely used in making interacted products. Annealing heat treatment involves heating metals up to an recrystalization temperature, and then allowing it to cool it very slowly to attain room temperature, hence results in

refined microstructure that possess better ductility and good toughness. Most of the Metal Matrix Composites will undergo annealing before being processed for cold forming, in order to reduce the load and energy needed for the process, and to allow the metal to undergo large deformations without failure.

PREPARATION OF COMPOSITES

Chemical composition of Steel EN 24 7075 alloy series is given in Table 1 was used here as the matrix material. The silicon carbide is used as reinforcement material which is hard material with better resistance to wear property. The MMC's were fabricated by liquid metallurgy technique. Silicon carbide particles (0%, 2%, 4%, and 6% by weight) were added into the vortex of the effectively degassed molten steel EN24. The stirrer blade was designed such a way that while rotating the silicon carbide particles move up in molten metal and distributed thoroughly, equally in the casting. The annealing was done to refine the microstructure. This was performed in a muffle furnace. The specimen was kept into the furnace and stayed until it reached a temperature of 860oC. This took about an hour and thirty minutes to achieve it and later kept in the surrounding temperature for around 30 minutes further, to cool down.

Table 1: Composition of Steel EN24

Elements	C	Si	MN	S	P	Cr	Mo	Ni	Fe
% by weight	0.36	0.35	0.45/0.70	0.04	0.035	1.00/1.40	0.20/0.35	1.30/1.70	Remaining

Tests

The prepared specimens were subjected to Hardness Test – Using Brinell Hardness test, Compression Test and Microstructural Analysis. Brinell's hardness test is conducted by using a spherical hardened steel ball indenter of diameter 10mm pressed against the test specimen by applying a force of 3000 kg for duration of 10 seconds. The indentation diameter is measured by using a graduated low power microscope and in accordance with ASTM E10. Compression testing is the most common test conducted on steels to evaluate the resistance of the material against compressive force and to determine the ability of the material to recover after a specified compressive force is applied and even held it for a defined time period. The maximum stresses a material can withstand for a period under a load (constant or progressive) are calculated in accordance with ASTM E9 standards.

RESULTS AND DISCUSSIONS

Hardness Test

Brinell's hardness tests were conducted on SiC Reinforced Steel EN24 with varying percentages of SiC - 2%, 4% and 6%. Results show that there is an increase of hardness from the Pure metal–Steel EN24, with increasing percentage of SiC. This is attributed to the fact that the bonding of the SiC in Steel EN24 matrix is reasonably good. It shows a steady increase in the hardness of the reinforced material. The best result was obtained for the composite with 6% SiC.

Table 2: BHN Values

Composition	BHN Values
EN24	200
EN24+2%SiC	239
EN24+4%SiC	285
EN24+6%SiC	298

The percentage of increase was found to increase by a maximum of 19.5%, which was observed when the pure Steel EN24 was reinforced with 2% SiC. On further increase, the percentage increase is not as significant, but overall there was an increase in hardness with an increase in the reinforcement.

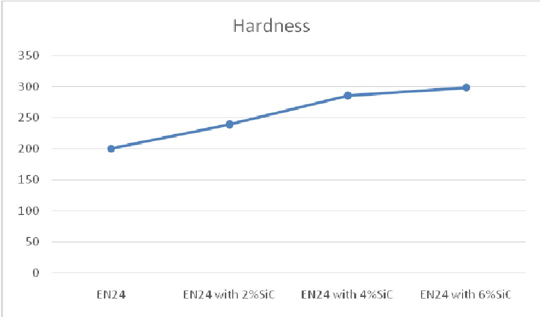
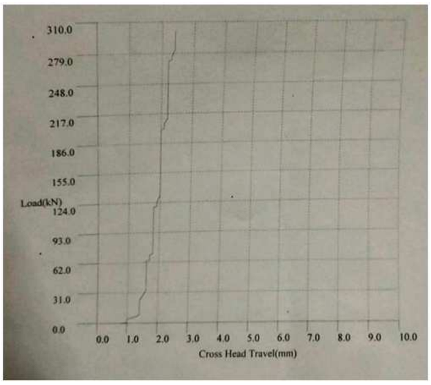
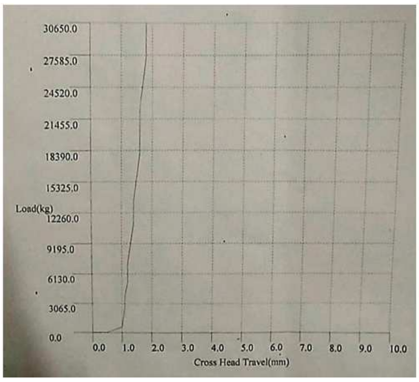


Figure 1: Hardness of Different Composition of Sic

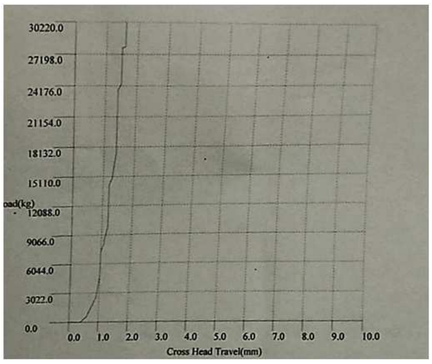
Compression Test

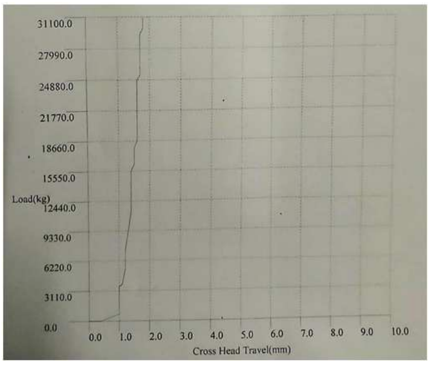
The characteristic curves for Cross Head Travel vs Load, has been plotted and is shown below. For the first specimen, i.e. the pure sample of Steel EN24, the material was found to fail at loads well beyond 30048kg. The compressive strength was found to be 42.19N/mm^2.





(a) **(b)**





(c) **(d)**

Figure 2: Cross Head Travel vs Load Applied
(a) EN24 (b) 2% SiC (c) 4% SiC (d) 6% SiC

The cross-head travel at peak was found to be 2.4mm thus proving that even a pure sample of Steel EN24 is capable of handling heavy compressive loads. When the second specimen sample was investigated, it was observed that

there was a remarkable increase in the compressive strength of the material when reinforced with 2% SiC. The material failed beyond a load of 30646.55kg. The compressive strength increased to 41.13kg/mm2. However, Steel EN24with4%SiC, we found that the compressive strength decreased slightly and was 43.61 kg/mm2. The same was the case with the 6% reinforcement of SiC, the compressive strength decreased further to allow of 44Kg/mm2. This decrease can be attributed to the formation of clusters of SiC in the composite. The decrease was a negligible amount from 2 % to 4% probably because of start formation of clusters, but at 6% larger amount of clusters were observed microscopically. The variation of compressive strength with varying percentage of SiC is shown below.

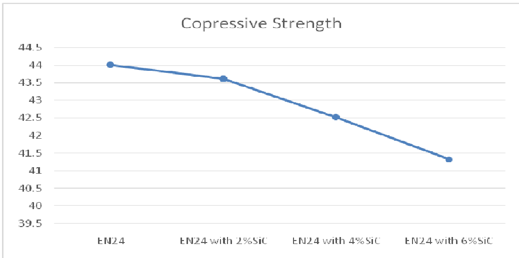


Figure 3: Compression Strength of EN24 and on Addition of Sic

Microstructure Analysis

For the last specimen, the microstructural analysis showed a Martensitic matrix structure. Formation of martensite is generally seen in carbon steels because the rapid quenching of the austenite structure forms when steel quenched at such a high rate so that carbon atoms will not get sufficient time to diffuse out of the crystal structure in large enough quantities to form cementite structure (Fe3C). It is a very hard form of steel crystalline structure. The change in the microstructure of steel can be attributed to the presence of a high percentage of SiC in the steel Matrix of the Composite.

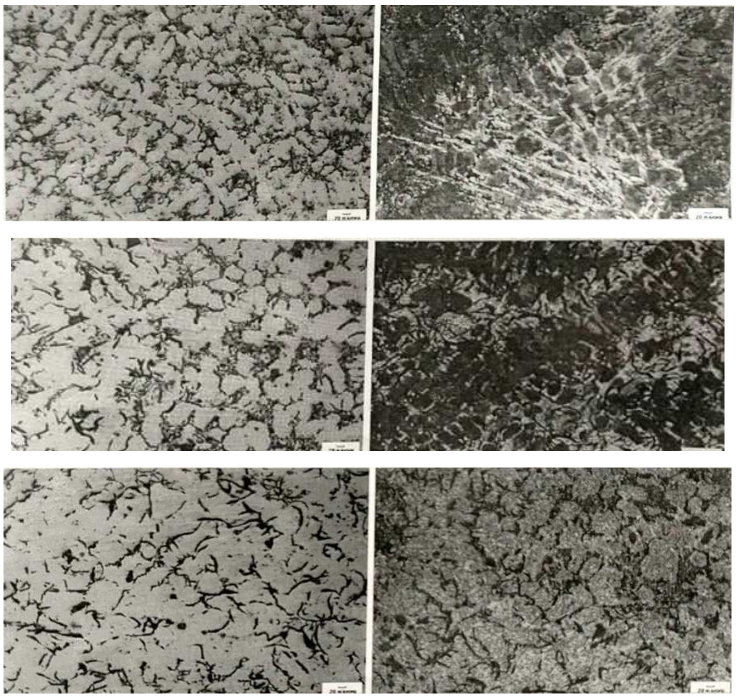


Figure 4: Microstructure Analysis
(a) Pure EN24, (b) 2% Sic, (c) 4% Sic, (d) 6% Sic

CONCLUSIONS

In this investigation, metal matrix composites containing2%, 4% and 6% SiC as reinforcement in base matrix of pure Steel EN24 were fabricated by using a stir casting process. Studies and tests were conducted on the specimens to ascertain the metallurgical and mechanical properties. The hardness of the composite is increased with the systematic increasing percentage of SiC, maximum increase was obtained from the specimen with 6% SiC from 200BHN to 298BHN. The compression test on the specimens also showed an noticeable increase in compression strength compared with pure steel EN24. 40kg/mm2 to 44kg/mm2 but the amount of improvement from 4% SiC to 6% SiC is very small compared to 2% SiC to 4% SiC. The microstructures thus show the increasing content of reinforcements in the Cast iron- Molybdenum matrix and therefore it suggests that the distribution is uniform.

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